Leaf Temperatures and Transpiration

The temperatures of the leaves of several plants growing on the summit of Pico del Oeste were measured on 7 and 8 January 1968, using a portable infrared radiometer. A detailed description of this infrared thermometer is given by Gates (1968c). The infrared thermometer senses the radiation emitted by a leaf and from the blackbody radiation law converts the response to the surface temperature of the leaf. Temperature readings are accurate to 0.3°C. Air temperature was measured with a dial thermometer and the wind speed with a hand held anemometer. The forest on the summit is dominated by *Tabebuia rigida* and *Ocotea spathulata*. The leaves of these plants are approximately 6 to 8 cm. in width.

The Q_{abs} is estimated at 0.57 cal cm^{-2} min^{-1}. The relative humidity of the air was about 85 per cent. By use of the energy budget, Eqn. (1), the relationship between transpiration rate and leaf temperature as a function of humidity and internal diffusion resistance for leaves of 6×8 cm. dimension, at an air temperature of 17°C and a wind speed of 100 cm sec^{-1} (2.2 mph) is shown in Fig. 1. It is possible to read from the graph the expected transpiration rate, if the leaf temperature is known. Assuming an internal resistance for the leaf of 5 cm sec^{-1}, it is anticipated that the leaves of the canopy would transpire about 1.5×10^{-5} gm cm^{-2} sec^{-1}, as shown by point A in Fig. 1.

The canopy then became illuminated with an increased amount of sunshine to give an amount of absorbed radiation of about 0.62 cal cm^{-2} min^{-1}. These conditions are represented by point B in Fig. 1. The leaf temperature was measured to be 18°C and the transpiration rate is 3.5×10^{-5} gm cm^{-2} min^{-1}. A few moments later the canopy was illuminated with more sunshine as the clouds thinned and the leaf temperature became 21°C. The conditions for the leaf are represented now by point C in Fig. 1, which indicates the transpiration rate as 6.3×10^{-5} gm cm^{-2} min^{-1} at an absorbed radiation of about 0.78 cal cm^{-2} min^{-1}. Since the internal diffusion resistance of the leaves of the canopy was not measured, it is possible that it was different than 5 sec cm^{-1}. Since the leaves were highly sclerophyllic, it is likely that the internal resistance was not less than 5 sec cm^{-1}. It may have been greater than 5 sec cm^{-1}. If it were 10 cm sec^{-1}, the transpiration rates would have been cut in half and the points referred to would be shown by a, b, and c respectively.

Transpiration Rate

A more accurate way to measure the transpiration rate of the leaves of the canopy is to sever a leaf, mount it side by side with an attached leaf and measure the temperature difference of the two leaves. If this is done, it is possible to use the energy budget computation to determine the transpiration rate of the attached leaf. On the basis that the severed leaf closes its stomates within about 15 minutes but that it absorbs the same amount of radiation as the attached leaf, one can read from Figure 1 the

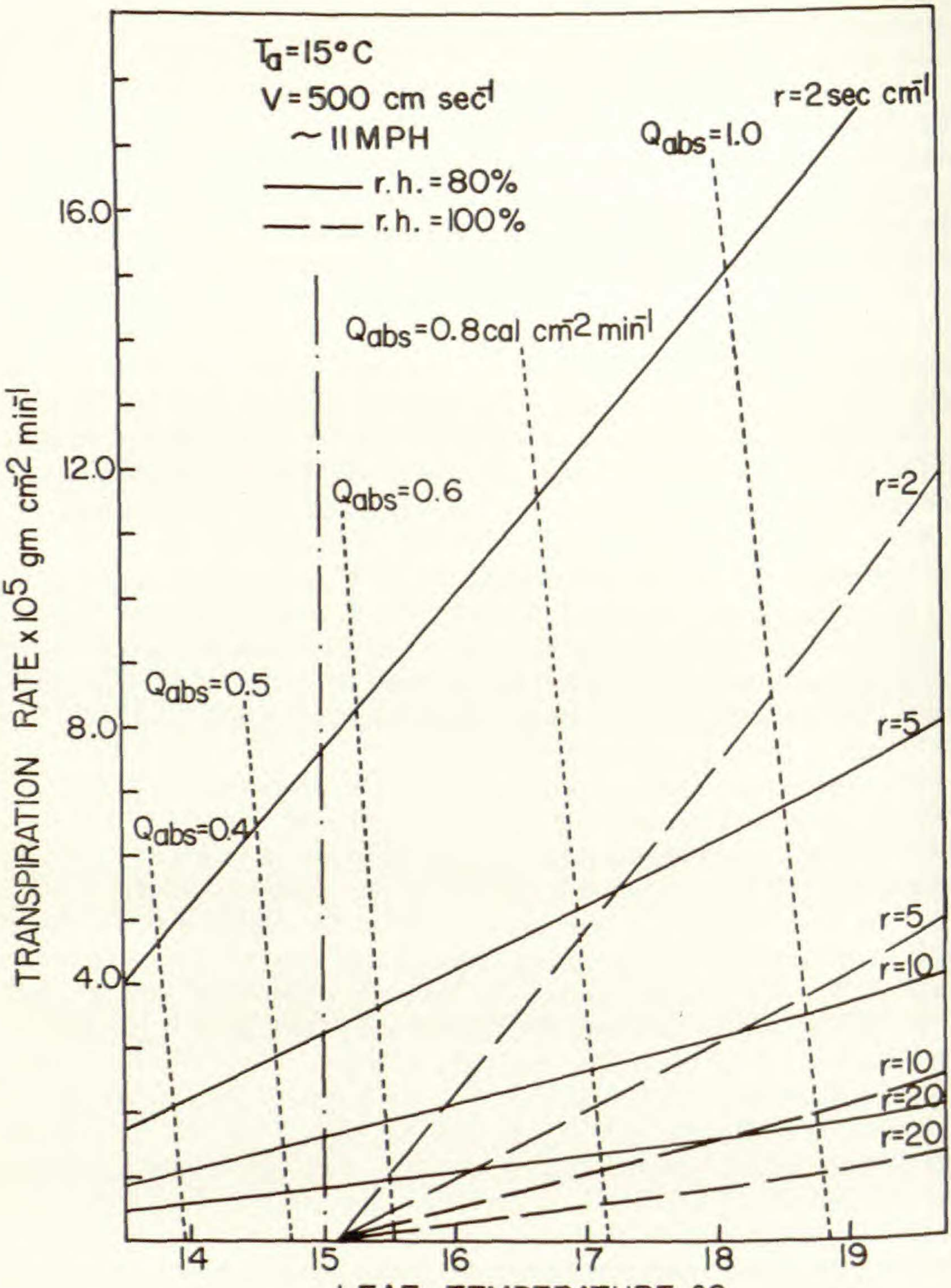

FIG. 1. Transpiration rate and leaf temperature as a function of the absorbed radiation, relative humidity, and internal diffusion resistance for leaves of dimension 6 × 10 cm. at an air temperature of 17°C and wind speed of 100 cm sec^{-1}.

transpiration rate corresponding to a measured temperature difference between the two leaves. When the radiation absorbed was about 0.8 cal cm^{-2} min^{-1}, achieved by direct sun incident on the leaf through a break in the clouds, and the wind speed was 2.5 mph, the temperature difference between a severed and an attached leaf was 0.8°C. According to

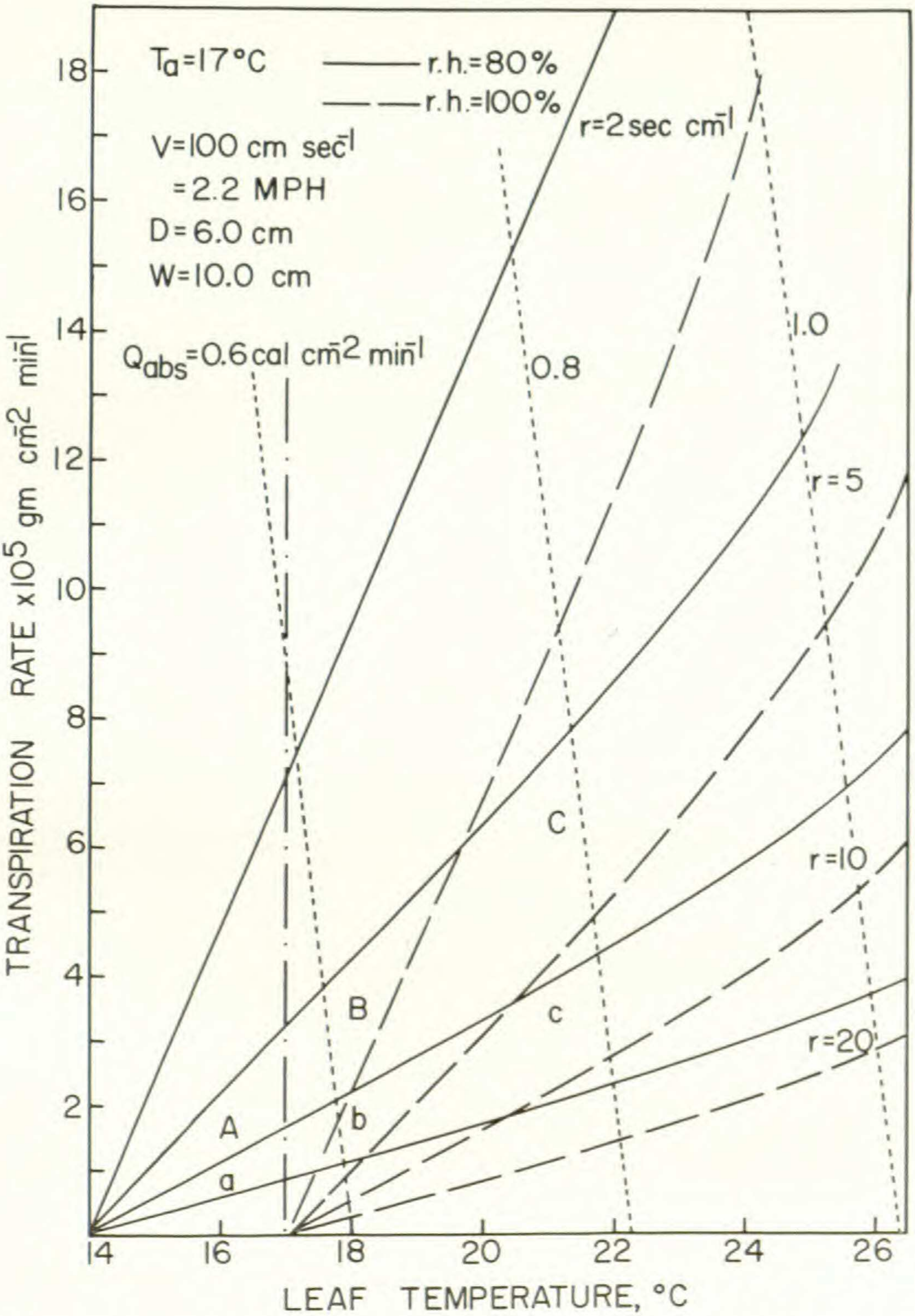

FIG. 2. Transpiration rate and leaf temperature as a function of the absorbed radiation, relative humidity, and internal diffusion resistance for leaves of dimension 6 × 10 cm. at an air temperature of 15°C and a wind speed of 500 cm sec^{-1}.

FIGURE 1, the transpiration rate was about 6.3×10^{-5} gm cm^{-2} min^{-1}, a position just to right of C. This would confirm the estimate that the internal resistance of the leaf was about 5 sec cm^{-1}.

CONSEQUENCES FOR AVERAGE CONDITIONS

If the wind speed increases to 11 mph and the air temperature is 15°C, then the relationship between transpiration rate and leaf temperature is shown in FIGURE 2. Once again it is evident that for Q_{abs} between 0.5 and 0.8 cal cm^{-2} min^{-1} and relative humidities of 80 to 100 percent, the leaves of the canopy do transpire. These transpiration rates are very low compared with more normal or frequent conditions when transpiration rates will exceed 10^{-4} gm cm^{-2} min^{-1}. The values for the forest on Pico del Oeste were low, but not zero by any means.

The leaf temperatures of the plants on Pico del Oeste probably never drop below 59°F (15°C) nor become warmer than 77°F (25°C). These temperatures are probably slightly below optimum for these sub-tropical species as concerns their photosynthesis and growth. Optimum temperature for these plants may be 30 to 35°C, but we do not really know. If they are at suboptimum in temperature, it would reduce their growth rate only slightly. On the other hand, if the light level is very much suboptimal then photosynthesis is strongly reduced. At the light levels measured to occur on the peak, it would appear that about half the maximum photosynthesis occurs for *Ocotea* and *Tabebuia*. In the absence of specific measurements of the photosynthetic rate as a function of leaf temperature and light intensity, it must be admitted that this is only conjectural.

TABLE 1. **Summary of climate data for Pico del Oeste**

	July	August	September
Max. Temp. °F	69.2	70.4	70.7
Min. Temp. °F	66.3	66.9	66.0
Rel. Hum. %	94.6	91.5	84.4
Min. Rel. Hum. %	83	72	65

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THE ECOLOGY OF AN ELFIN FOREST IN PUERTO RICO, 5. CHROMOSOME NUMBERS OF SOME FLOWERING PLANTS

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ONE OBJECTIVE of this elfin-forest study was to obtain chromosome counts for as many of the species of flowering plants growing on the research site as practicable.[1] The purpose was to evaluate any relationship which might be found to exist between chromosomal level and adaptation to an extreme habitat (in terms of climate). Although it has been stated in previous papers in this series that the environment of Pico del Oeste is a fairly rigorous one for the investigators, it is harder to obtain direct evidence that it is difficult for the plants as well. In some respects, such as temperature and perhaps rainfall, the environment may be excellent for the promotion of plant growth but in others, such as low light quantities, it must be considered rigorous. Perhaps the best evidence, although indirect, is furnished by the relatively small number of angiosperm species represented in the flora. The absence of certain well-developed tropical families may be additional evidence. We believe Pico del Oeste is a type of ecological extreme and is one in which few species are capable of extended persistence. Several weedy species were introduced accidentally into the research site and it will be of considerable interest to determine the duration of their survival. All species now represented in the flora may not be equally adapted to the prevailing environmental conditions and those which are not may be the same ones which appear to be having difficulty in maintaining a regular cycle of sexual reproduction.

Fixation of bud material was with a fresh mixture of three parts absolute ethyl alcohol and one part glacial acetic acid although in special cases this was modified to six parts alcohol, three parts chloroform and one part glacial acetic acid. Buds were rinsed and hydrated to 95 percent ethyl alcohol after 12 to 24 hours, except with the Rubiaceae where fixation was limited to 15 minutes. The material was then refrigerated until transported to Cambridge by air. A standard squash technique utilizing aceto-carmine stain was used for staining pollen-mother-cell divisions. In

[1] This note could not have been as nearly complete without the devoted talents of Mrs. Lily M. Rüdenberg who is responsible for some of the original counts and for verification of others. I am very grateful for her interest and persistence in handling some of the difficult material. Acknowledgment is made to the National Science Foundation for a grant to Richard A. Howard (GB: 3975) which directly supported the major portion of this study. I am especially grateful to Mr. Joseph B. Martinson for providing facilities and generous hospitality on numerous pleasant occasions in Puerto Rico.

those instances where it was necessary to examine mitotic material (greenhouse grown in Jamaica Plain) several pre-fixatives were used and the root tips were stained by the feulgen technique.

Obtaining chromosome counts proved to be a difficult and frustrating undertaking for a variety of practical as well as technical reasons. Among the former the most important being the variety of personnel who prepared flower buds for subsequent staining and examination. In general it does not seem to be possible to impress strongly enough the necessity of working within the tight perimeters necessary for successful fixation during periods of active meiosis. We suspect that our chief problem in this regard was timing in connection with hours of sunshine. The number of sunlight hours being so few that there was a "desperation" attempt to fix material as soon as the sun appeared and thus to avoid the possibility of not obtaining material. Too often this proved totally unsatisfactory and as an alternative we employed a notebook containing fixation information, including proper bud size, time of day, etc., for individual species. Ordinarily, we would not consider it appropriate to present this type of information and we do so in the present report only in the hope that it may be of some use in another study.

The technical failures are more difficult to assess. There is little question that working with a variety of unfamiliar groups is an inefficient method. Under these circumstances it is difficult, if not impossible, to work out the subtleties of technique often necessary in some plant groups. Two of our more interesting failures are presented in the belief that often more is learned in failure than in instant success. One such failure was *Marcgravia sintenisii* Urban, in which we did not obtain meiotic or countable mitotic figures in spite of repeated attempts. We also examined material of a related species kindly sent to us by our friend Dr. Ding Hou of the Rijksherbarium, Leiden. As we failed with this species, too, we are now inclined to believe that the fault lies with the technique. Meiosis occurs when the flower buds are very small and this adds measurably to the difficulty. Partly as a result of these failures, *M. sintenisii* was kept under careful observation and we have been able to gather some information about its reproductive biology. This data will be reported in detail at a later date.

Another instance in which results were not obtained was from *Tabebuia rigida* Urban, a conspicuous and very distinct species of the Bignoniaceae. It is one of the dominant trees of the elfin forest in the Luquillo range. Observation over several years indicates that this magenta-flowered species is in bloom in all months of the year. There is no indication of increased flowering (i.e., a flowering peak) during any specific part of the year. Individual flowers open between 8 and 8:30 A.M. when most of them are visited by bananaquits (*Coereba flaveola*). These birds approach the flower from the rear and with a quick thrust of the bill split the corolla tube lengthwise from the base in order to obtain the nectar contained within. Most flowers are damaged in this way by 9:30 A.M. While the